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Heuristics for N Job M Machine Flowshop Batch Processing With Breakdown Times

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Abstract: ***Flow shop scheduling is a typical combinatorial optimization problem, where each job has to go through the processing in each and every machine on the shop floor. Here considered the basic form of flow shop scheduling i.e. Two machine Flow Shop batch processing with type two transportation i.e. transportation of jobs from machine shop to dispatch unit. For this problem we investigate the optimal property and propose an algorithm which includes Johnson's algorithm. After the sequences of jobs are formed we implement breakdown time at two intervals and form another solution. This problem is extended to Njob Mmachine problem to find optimal solution. The performance measure taken here is makes pan and mean weighted flow time of jobs. This type of problem comes under NP hard category.***

Keywords: Flowshop scheduling, Breakdown times, NP hard.

1. Introduction

Production scheduling is generally considered to be the one of the most significant issue in the planning and operation of a manufacturing system. Proficient scheduling leads to increase in capacity utilization efficiency and hence thereby reducing the time required to complete jobs. The main focus of this paper is scheduling of N jobs M machine flowshop batch processing problem with breakdown of machines. Every batch considered here has common due date. Initially an efficient algorithm was proposed for two machine case and the same algorithm was extended to M machine case. After the sequences of jobs are formed we implement break down times of machines which is often called preemption according to algorithm predicted by A. B. Chandramouli.

2. Problem Statement and Notations

We consider N job M machine flowshop scheduling batch processing problems with type2 transportations. For this we initially consider two machine n job flowshop scheduling problems and a heuristic solution is formed and the same heuristics is extended to m machine N job scheduling problems. The flowshop environment consists of N independent jobs N={J1,J2,J3…..Jn} to be processed on two machines M1 and M2.Every job comprises two operations associated with respective processing times on both machines. Second operation on M2 cannot be started until the first operation is completed. All the jobs are continuously available at time zero. Every job to be processed is associated with job size Sj and also contains identical due date. In this case breakdown of machines are occurred in two intervals.

After processing in the manufacturing cell, finished jobs are delivered to dispatch section by vehicles. Assume there is only one vehicle available with a limited capacity i.e.) limited batch size. The capacity of vehicle (c) is measured by total physical space that vehicle provides for one delivery. If the sizes of all jobs are equal, the vehicle capacity can be represented by number of jobs. The transporting time from machine shop to dispatch section is denoted by T, which is the sum of t1 and t2, where t1 is the time taken to travel form machine shop to dispatch section and t2 is the time taken to travel from dispatch section to machine shop. In most of the cases t1 and t2 are equal. Both t1 and t2 are independent of the jobs processed. The breakdown of machines affects only the makespan and T is independent from breakdown times [1, 2].

- P1j – Processing time of jth job in Machine M1
- P2j- Processing time of jth job in Machine M2
- Bk –Batch
- Sj – Jobsize.
- C-Capacity of vehicle.
- Pk-Period of time for processing all jobs in Bk.
- P1k-Sum of processing times on M1 for jobs in Bk.
- P2k- Sum of processing times on M2 for jobs in Bk.
- ϕk – Sum of idle times on M1.
- ρk -Sum of idle times on M2.

3. Literature Survey

Initially S.M.Johnson [1] in 1954 introduced the basic two and three stage flowshop scheduling problems. In this he considered only permutation schedule problems and proposed O (nlogn) algorithm for two stage problem. The complexity of 3 stage problem belongs to NP hard (Garey et al [1]). More recently the amount of research devoted to minimization of sum of job completion times has increased.Flowtime minimization leads to stable or even use of resources, a rapid turnaround of jobs and minimization of in process inventory [6]. Simchi-Levi et al [5] proposes a new worst case results for the bin packing problem. The paper work provides information about the worst case testing for bin packing problems. C. Y. Lee et al [4] investigated machine scheduling models that impose constraints on both transportation capacity and transportation times. From the journals of Lee et al [4], Chang et al [8] the complexity status for two machine flowshop is given as F2(D),k=1|v=1,c|∑Cj is strongly NP hard. C. Rajendran[3] proposes an efficient heuristic for scheduling in a flowshop to minimize total weighted flowtime of jobs. This paper work provides a heuristic approach to find the sequence for optimization of total weighted flowtime of jobs.

T. C. E. Cheng et al [7] explains the parallel machine batching problems. He considers a scheduling problem in which n independent and simultaneously available jobs are to be processed on m identical parallel machines. A. B. Chandramouli [6] at 2005 considers a flowshop scheduling problems. It provides a new simple heuristic algorithm for a '3-Machine, n job' flow-shop scheduling problem in which jobs are attached with weights to indicate their relative importance and the transportation time and break down intervals of machine are given. A heuristic approach method to find optimal or near optimal sequence minimizing the total weighted mean production flow time for the problem has been discussed. Guzin ozdagoglu [9] includes a sample case of a sequencing problem of flow shop system for which a simulated annealing algorithm is presented. In addition, the results obtained from the simulated annealing algorithm are compared with the results of scheduling software LEKIN for the same problem. Finally, a simulated annealing algorithm is obtained which is very close to the results of LEKIN which is broadly used within the scheduling applications according to the objective under consideration.

4. Proof of NP Hard

Lemma: 1 The scheduling problem 1(D),k=1|v=1,c=1|∑Cj is NP hard in strong sense.

3-Partition problem

Given a set A={a1,a2,a3,a4….a3m} of 3m elements with positive integer size s(a) for each a C A such that for integer z, (z/4) <s(a)< (z/2) and ∑s(a)=mz decide if A can be partitioned in to m disjoint 3 element subsets A1,A2,A3…..Am such that ∑s(a)=z for each j=1,2,3,….m.

Lemma: 2 The scheduling problem F2(D) k=1|v=1,c=z|∑Cjis NP hard in strong sense

Proof. With the complexity hierarchy, by setting all of the processing times on M1 orM2 are 0,the scheduling problem 1(D) k=1|v=1,c=z|∑Cj is a special case of the more general problem F2(D) k=1|v=1,c=z|∑Cj. Since 1(D) k=1|v=1,c=z|∑Cj is NP hard in the strong sense, which is proved in Theorem2, the scheduling problem F2(D) k=1|v=1,c=z|∑Cj is also NP-hard in strong sense.

Lemma: 3The scheduling problem F2 (D) k=1|v=1,c=z|Cmax is NP hard in strong sense.

Consider a special case of F2 (D) k=1|v=1,c=z| Cmax in which for every job, the processing times of both operations are zero. Hence all of the jobs are ready for delivering to the customer at beginning. In such a case, because of the constant transportation time, minimization of the no. of delivery batches will achieve the optimality and thus the problem can be regarded as a bin packing problem, which is a well-known strongly NP hard problem. Therefore, the problem that we considered is also NP hard in the strong sense.[3,4]

5. Heuristics for 2 Machine Flow Shop Batch Processing Problems with Breakdown Times

Step:1 Assign jobs into batches by First Fit Decreasing algorithm. Set the total number of resulting batches be b,b ≤ n.
Step:2 The jobs within the batches are sequenced using Johnson's algorithm i.e., SPT(I)-LPT(II) schedule.
Step:3 Calculate the following three values for each batch say Bk in which jobs are scheduled in SPT(I)-LPT(II) order.

$\Delta 1 = \Phi k = Pk – \Sigma P1j$
$\Delta 2 = \rho k = Pk – \Sigma P2j$
$\Delta 3 = \max (Pk-T,0)$

Step: 3a Let Sb={B1,B2….} be the set of batches in which the processing sequence is undecided and another two ordered set S1 and S2 which are both initially empty, be the set of scheduled batches. Pick the batch from SB with smallest value over all values obtained in step1.If the value belongs to Δ1, and then set the batch into S1 as the first element. On the other hand, if the value belongs to Δ2 or Δ3, then set the batch in to S2 as the last one. Eliminate the chosen batch from SB.
Step: 3b Iterate step2 until all the batches have its position, i.e., SB is an empty set. Therefore, the permutation of S2 U S1 is indeed the processing sequence of the batches.
Step: 4 Starting with B1, assign jobs in Bk to the machines, for K=1,2,….b
Step: 5 Dispatch each completed but undelivered batch whenever the vehicle becomes available. If multiple batches have been completed when the vehicle becomes available, dispatch the batch with the smallest index.
Step:5A : The sequence of batches provides the sequence of overall jobs. Consider the sequence of all jobs and Cmax value.[5]
Step: 6: Denote the sequence of all jobs as flowtime in respective machines.Check for the structural conditions [9].
Step: 7: Implement the effect of breakdown times in the flowtime pattern.
Step: 8: Let us consider (a,b) as the breakdown time interval (since deterministic scheduling) then implement the value a to b in the flow processing of the machines.
Step:9: Following Step7 leads to addition of breakdown times on processing time that the job processing in particular machine. This means that the jobs are processed up to the start of the breakdown times and resume the operation after the end of breakdown time.

Step: 10: Update the changes in the changes in the upcoming processing times because the breakdown interval influences the remaining process if the machines.
Step:11 Calculate the mean flowtime by using the following formula

$$\bar{F}_w = \frac{\sum_{i=1}^{n} w_i f_i}{\sum_{i=1}^{n} w_i}$$

Where fi be the flow time of the ith job, Wi be the weightage of the ith job

Extension of Algorithm to N Jobs M Machine Flow Shop Batch Processing with Breakdown Times

Step:1 Assign jobs into batches by First Fit Decreasing algorithm. Set the total number of resulting batches be b,b ≤ n.
Step:2 The jobs within the batches are sequenced using Software based Local search Heuristics algorithm.
Step:3 Calculate the following values for each batch say Bk in which jobs are scheduled by using Local search Heuristics.

$\Delta 1 = Pk - \Sigma P1j$
$\Delta 2 = Pk - \Sigma P2j$
$\Delta m = Pk - \Sigma Pmj$
$\Delta m+1 = \max (Pk-T,0)$

Where m denotes the no. of machines

Step: 3 Form Δ'1 and Δ'2 by adding the values of Δ1(m/2) and Δ2(m/2) .
Step: 4 Let SB={B1,B2….} be the set of batches in which the processing sequence is undecided and another two ordered set S1 and S2 which are both initially empty, be the set of scheduled batches. Pick the batch from SB with smallest value over all values obtained in step1.If the value belongs to Δ'1, and then set the batch into S1 as the first element. On the other hand, if the value belongs to Δ'2 or Δm+1, then set the batch in to S2 as the last one. Eliminate the chosen batch from SB.
Step:5 Iterate step2 until all the batches have its position, i.e., SB is an empty set. Therefore, the permutation of S2 U S1 is indeed the processing sequence of the batches.
Step: 6 Starting with B1, assign jobs in Bk to the machines, for K=1,2,….b
Step: 7 Dispatch each completed but undelivered batch whenever the vehicle becomes available. If multiple batches have been completed when the vehicle becomes available, dispatch the batch with the smallest index.
Step: 8: Implement the effect of breakdown times in the flow time pattern.
Step: 8A: Let us consider (a,b) as the breakdown time interval (since deterministic scheduling) then implement the value a to b in the flow processing of the machines.
Step:9: Following Step7 leads to addition of breakdown times on processing time that the job processing in particular machine. This means that the jobs are processed up to the start of the breakdown times and resume the operation after the end of breakdown time.
Step:9A: Update the changes in the changes in the upcoming processing times because the breakdown interval influences the remaining process if the machines.
Step:10: Calculate the mean flow time by using the following formula

$$\bar{F}_w = \frac{\sum_{i=1}^{n} w_i f_i}{\sum_{i=1}^{n} w_i}$$

Where fi be the flow time of the ith job

Wi be the weightage of the ith job. Since we are dealing with mono weightage jobs sum of Wicorresponds to the total number of jobs.

6. Illustration of Heuristic Procedure

In the previous chapters we proposed the algorithms formmachine flow shop batch processing with breakdown times. To illustrate the algorithm we select an environment of 10 machine and 20 jobs with common due date and distinct job size. The problem considered here is deterministic nature and all the values are known. The typical data input for the problem is shown here.[6]

No. of the machine: 10.
Machine availability: at zero
Breakdown time: (15-17), (145-147)
No. of the jobs: 20.
Job type: Independent jobs.
Job availability: all are available at zero.
Environment: Flowshop.
Sequence: Sequenced as M1 – M2 – M3– M4– M5– M6– M7– M8– M9– M10
Earliness cost: 1/unit
Tardiness cost: 1/unit.
Weightage of the jobs: Mono weightage jobs.
Processing: Batch processing.
Batch size: 20.
Transportation time to dispatch center: 15.
Transportation time between the machines: not considered.
Complexity of the problem: NP hard [chapter 4]
Performance ratio of the Algorithm: 4 [chapter 6]

Sub algorithms used:

1. First fit Decreasing Algorithm
2. Software based Local Search Heuristic.

The processing time of each job on machine 1 and machine 2 and the job size of the respective jobs are tabulated as follows.

Table 1: Processing time and job size for m machines

Jobs	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	S_j
1	5	2	3	5	7	9	7	8	2	7	3
2	2	6	4	2	6	2	5	2	6	1	4
3	1	2	2	1	3	7	2	5	4	4	2
4	7	5	6	3	2	3	2	4	2	2	1
5	6	6	1	8	6	4	3	9	6	4	4
6	3	7	5	2	2	1	5	3	2	6	3
7	7	2	4	6	5	5	1	2	5	2	2
8	5	1	7	1	7	3	6	6	2	2	1
9	7	8	6	9	1	8	2	1	6	6	4
10	4	3	5	8	3	1	3	8	3	7	5
11	5	2	1	7	6	3	7	5	7	4	2
12	2	6	2	5	6	7	2	1	8	3	3
13	3	4	2	6	1	5	4	7	6	5	4
14	5	2	1	3	8	2	6	1	9	8	3
15	7	6	3	2	6	2	5	7	1	3	2
16	9	2	7	3	4	1	5	3	8	1	1
17	7	5	2	2	3	5	1	6	2	3	3
18	8	2	5	4	9	3	2	6	1	8	4
19	2	6	4	2	6	2	5	2	6	3	5
20	7	1	4	2	4	6	2	2	6	7	2

The above data are used as input in the algorithm to find Cmax and mean weighted flow time. The major steps in the algorithm are;

Formation of batches – FFD algorithm.
Sequence of Jobs – Johnson's algorithm.
Parameter calculation
Sequence of batches
Breakdown implementation
Flow time calculation.

Step: 1: Formation of batches – FFD algorithm:
Arrange the jobs in non-increasing order of sizes.
J10-J19- J 2- J 5- J 9- J 13- J 18- J 1- J 6- J 12- J 14- J 17- J 03- J 07- J 11- J 15- J 20- J 4- J 8- J 16.
Formation of batches by First Fit Decreasing algorithm
B1={J10,J19,J2,J5,J3} Batch size=20
B2={J9,J13,J18,J1,J6,J7} Batch size=20
B3={J12,J14,J17,J11,J15,J20,J4,J8,J10} Batch size=18

In the jobs from 1 to 20 J10 and J19 are the jobs having highest job sizes hence are placed in the top places of the batch 1.The total batch size of the processing is 58.Hence 20 jobs forms three batches exactly. The last batch B3 is the only batch which has the batch size as 18.But during the transportation B3 is also considered equivalent to other batches. The batches B1, consists of only 5 jobs while the batches B2 consists of 6 jobs and B3 consists of 9 jobs. In this the batch B3 consists the jobs with very low job size in the processing cell.[7]

Step:2: Sequence of jobs within the batches.

Hence the problem is Fm||Cmax and from many researches it is proved that Local search Heuristic provides the optimal solution to these kinds of problems. So we use Local search Heuristic rule for the sequence of jobs within each batch. Sequence of Batch B1: B1={J10,J19,J2,J5,J3}, Batch size=20

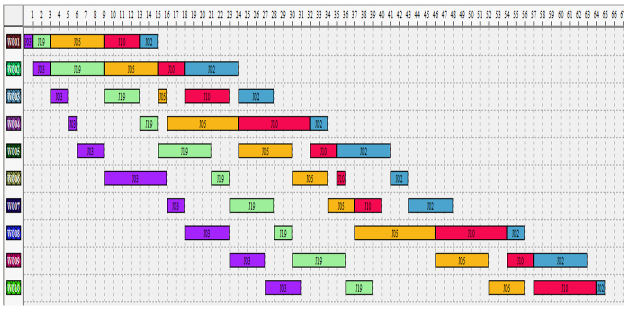

Figure 1: Gantt chart for sequence of jobs within batch 1

By applying Local search Heuristic we obtain C_{max} = 65

Job sequence = $J_{03} – J_{19} – J_{05} – J_{10} – J_{02}$.

Sequence of Batch B_2: $B_2=\{J_9,J_{13},J_{18},J_1,J_6,J_7\}$ Batch size=20

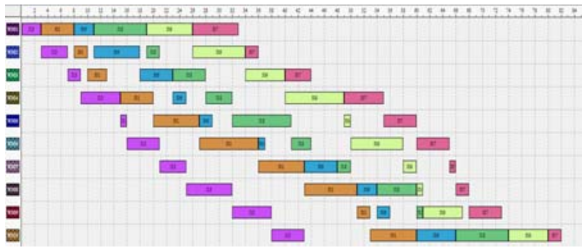

Figure 2: Gantt chart for sequence of jobs within batch 2

By applying Local search Heuristic we obtain Cmax = 78.
Job sequence = J13 – J01 – J06– J18– J09– J07.
Sequence of Batch B2:
B3= {J12, J14, J17, J11, J15, J20, J4, J8, J10}
Batchsize=18

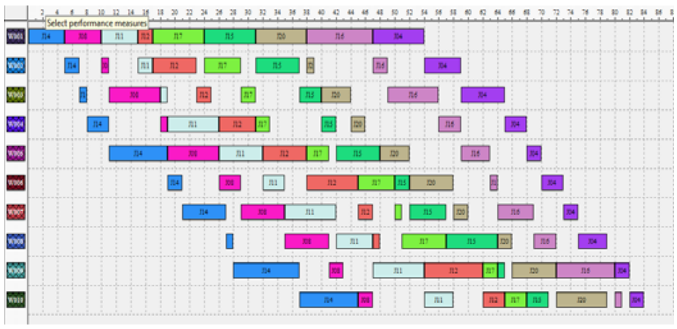

Figure 3: Gantt chart for sequence of jobs within batch 3

By applying Local search Heuristic we obtain Cmax = 83.
Job sequence = J14 – J08 – J11– J12– J17– J15– J20– J16– J04.

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Step:4: Parameter Calculation:

Calculate the following values for each batch say Bk in which jobs are scheduled by using Local search Heuristics.

- Δ1 = Pk – Σ P1j
- Δ2 = Pk – Σ P2j
- Δm = Pk – ΣPmj
- Δm+1 = max (Pk-T,0)
- Where m denotes the no. of machines.
- Form Δ'1 and Δ'2 by adding the values of Δ1(m/2) and Δ2(m/2) .
- Where, Pk-Period of time for processing all jobs in Bk.
- P1k-Sum of processing times on M1 for jobs in Bk.
- P2k- Sum of processing times on M2 for jobs in Bk.
- Δ1 – Sum of idle times on M1.
- Δ2 –Sum of idle times on M2.
- Δm –Sum of idle times on Mm.
- T- Transportation time

From these values only we can sequence the set of batches formed through FFD algorithm. Here the transportation time is 15.Hence for the m machine flowshop scheduling batch processing problem the values are tabulated as follows.[8]

Table 2: List of sequence of batch and processing time of jobs in respective machines

B	Seq	P_k	P_{1k}	P_{2k}	P_{3k}	P_{4k}	P_{5k}	P_{6k}	P_{7k}	P_{8k}	P_{9k}	P_{10k}
1	3,19,5,10,2	65	15	23	15	19	22	16	23	24	25	19
2	13,1,6,18,9,7	82	33	25	25	32	25	31	21	27	22	34
3	14,08,11,12,17,15,20,16,04	84	49	29	33	28	46	32	36	35	45	33

Table 3: calculated values for Batches

	Δ_1	Δ_2	Δ_3	Δ_4	Δ_5	Δ_6	Δ_7	Δ_8	Δ_9	Δ_{10}	Δ_{11}
1	50	42	50	46	43	49	42	41	40	46	50
2	49	57	57	50	57	51	61	55	60	48	67
3	35	55	51	56	38	52	48	49	39	51	69

Let us form Δ'1 and Δ'2 by adding the values of Δ1(m/2) and Δ2(m/2)

Table 4: Summation of Δ1(m/2) and Δ2(m/2)

Δ'_1	Δ'_2	Δ_{11}
231	218	50
270	275	67
235	239	69

Step:4: Sequence of batches

Establish SB = {B1, B2, B3}.S2 U S1 = {} which is an empty set. From the table, the smallest value is 50 which lies in both Δ11. Hence place B1 at the end of S2 i.e.) S2 = {B1}. Remove that batch from SB. Then the repeat the procedure until SB becomes an empty set. Hence the optimal batch sequence is S2 U S1 i.e.) B3-B2-B1.It means that the overall sequence of the jobs to be processed in the machines is J14 – J08 – J11-J12 – J17 – J15– J20 – J16 – J04 – J17 -J13– J01 – J06-J18 –J09– J07 – J03-J19 - J05 – J10 – J02..By following this Gantt chart is obtained. The value of Cmax obtained through the proposed algorithm is 164.[9]

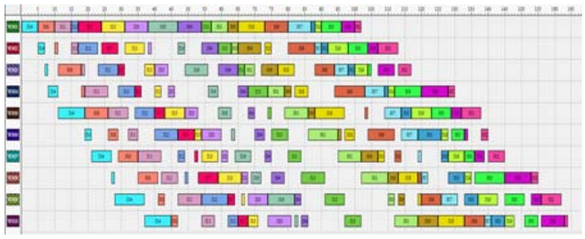

Figure 4: Overall sequences of jobs in three batches

Hence Cmax = 164.
Completion time for B3= 86.
Completion time for B2= 141.
Completion time for B1= 164.
Common Due date of the batches = 135
Early Batches = B3.
Tardy Batches =B1, B2.
JIT Batch = B6
Early cost = 49
Tardy cost = 6+29=35.
Total cost = 35+49=84.
Total completion time = 164.
Mean weighted flow time without breakdown = 54.95.
Step: 5: Breakdown implementation:

For the implementation of breakdown we have to formulate the optimal sequence as typical flow pattern. In our problem breakdown times are implemented in two intervals as (15-17) and (145-147) [since deterministic scheduling] .Initial step of break down calculation is sequence of jobs optimally. That we have done at the end of Step:4. asis J14 – J08 – J11-J12 – J17 – J15– J20 –J16 – J04 – J17 -J13– J01 – J06-J18 –J09– J07 – J03-J19 -J05 – J10 – J02.Second step is to denote the sequence as flow time in the machines.

Table 5: Flow time of jobs in respective machines

Job	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}
14	0-5	5-7	7-8	8-11	**11-19**	19-21	21-27	27-28	28-37	37-45
08	5-10	10-11	**11-18**	18-19	19-26	26-29	29-35	35-41	41-43	45-47
11	10-15	**15-17**	18-19	19-26	26-32	32-35	35-42	42-47	47-54	54-58
12	**15-17**	17-23	23-29	29-34	34-40	40-47	47-49	49-50	54-62	62-65
17	17-24	24-29	29-31	34-36	40-43	47-52	52-53	53-59	62-64	65-68
15	24-31	31-37	37-40	40-42	43-49	52-54	54-59	59-66	66-67	68-71
20	31-38	38-39	40-44	44-46	49-53	54-60	60-62	66-68	68-74	74-81
16	38-47	47-49	49-56	56-59	59-63	63-64	64-69	69-72	74-82	82-83
04	47-54	54-59	59-65	65-68	68-70	70-73	73-75	75-79	82-84	84-86
13	54-57	59-63	65-67	68-74	74-75	75-80	80-84	84-91	91-97	97-102
01	57-62	63-65	67-70	74-79	79-86	86-95	95-102	102-110	110-112	112-119
06	62-65	65-72	72-77	79-81	86-88	95-96	102-107	110-113	113-115	119-125
18	65-73	73-75	77-82	82-86	88-97	97-100	107-109	113-119	119-120	125-133
09	73-80	80-88	88-94	94-103	103-104	104-112	112-114	119-120	120-126	133-139
07	80-87	88-90	94-98	103-109	109-114	114-119	119-120	120-122	126-131	139-141
03	87-88	90-92	98-100	109-110	114-117	119-126	126-128	128-133	133-137	141-145
19	88-90	92-97	100-104	110-112	117-123	126-128	128-133	133-135	137-143	**145-148**
05	90-96	97-104	104-105	112-120	123-129	129-133	133 3-136	136-145	**145-151**	151-155
10	96-100	104-107	107-112	120-127	129-132	133-134	136-139	**145-153**	153-156	156-163
02	100-102	107-113	113-117	127-130	132-138	138-140	140-145.	153-155	156-162	163-164.

The jobs which are affected by implementation of breakdown times are highlighted.

J14 on M5,J08 on M3,J11 on M2,J12 on M1,J19 on M10,J05 on M9,J10 on M8

The initial breakdown causes some changes in second one.

Implementation of Breakdown times:

Table 6: Flowtime of jobs with breakdown in respective machines

Job	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}
14	0-5	5-7	7-8	8-11	**11-21**	21-23	23-29	29-30	30-39	39-47
08	5-10	10-11	**11-20**	20-21	21-28	28-31	31-37	37-43	43-45	47-49
11	10-15	**15-19**	20-21	21-28	28-34	34-37	37-44	44-49	49-56	56-60
12	**15-19**	19-25	25-31	31-36	36-42	42-49	49-51	51-52	56-64	64-67
17	19-26	26-31	31-33	36-38	42-45	49-54	54-55	55-61	64-66	67-70
15	26-33	33-39	39-42	42-44	45-51	54-56	56-61	61-68	68-69	70-73.
20	33-40	40-41	42-46	46-48	51-55	56-62	62-64	68-70	70-76	76-83
16	40-49	49-51	51-58	58-61	61-65	65-66	66-71	71-74	76-84	84-85
04	49-56	56-61	61-67	67-70	70-72	72-75	75-77	77-81	84-86	86-88
13	56-59	61-65	67-69	70-76	76-77	77-82	82-86	86-93	93-99	99-104
01	59-64	65-67	69-72	76-81	81-88	88-97	97-103	103-111	111-113	113-120
06	64-67	67-74	74-79	81-83	88-90	97-98	103-108	111-114	114-116	120-126
18	67-75	75-77	79-84	84-88	90-99	99-102	108-110	114-120	120-121	126-134
09	75-82	82-90	90-96	96-105	105-106	106-114	114-116	120-121	121-127	134-140
07	82-89	90-92	96-100	105-111	111-116	116-121	121-122	122-124	127-132	140-142
03	89-90	92-94	100-102	111-112	116-119	121-128	128-130	130-135	135-139	**142-148**
19	90-92	94-100	102-106	112-114	119-125	128-130	130-135	135-137	139-145	148-151
05	92-98	100-106	106-107	114-122	125-131	131-135	135-138	**138-149**	149-155	155-159
10	98-102	106-109	109-114	122-130	131-134	135-136	138-141	149-157	157-160	160-167
02	102-104	109-115	115-119	130-132	134-140	140-142	**142-149**	157-159	160-166	167-168.

Hence Cmax = 168
Completion time for B3= 88.
Completion time for B2= 142.
Completion time for B1= 168.
Common Due date of the batches = 135
Early Batches = B3.
Tardy Batches =B1, B2.
Early cost = 47
Tardy cost = 7+33= 40.
Total cost = 40+47=87.
Calculation of Total flow time for m machine without breakdown:

$$\bar{F}_w = \frac{\sum_{i=1}^{n} w_i f_i}{\sum_{i=1}^{n} w_i}$$

∑wi fi= 45+(47-5)+(58-10)+(65-15)+(68-17)+(71-24)+(81-31)+(83-38)+(86- 47)+(102-54)+(119-57)+(125-62)+(133-65)+(139-73)(141-80)+(145-87)+(148-88)+(155-90)+(163-96)+(164-100).

=45+42+48+50+51+47+50+45+39+48+62+63+68+66+61 +58+60+65+67+64.
=1099.
∑wi fi= 1099
Fw= 1099/20 = 54.95.

Calculation of Total flow time for m machine with breakdown:

$$\bar{F}_w = \frac{\sum_{i=1}^{n} w_i f_i}{\sum_{i=1}^{n} w_i}$$

∑wi fi= 47+(49-5)+(60-10)+(67-15)+(70-19)+(73-26)+(83-33)+(85-40)+(88-49)+(104-56)+(120-59)+(126-64)+(134-67)+(140-75)+(142-82)+(148-89)+(151-90)+(159-92)+(167-98)+(168-102)=
47+44+50+52+51+47+50+45+39+48+61+62+67+65+60+ 59+61+67+69+66
=1110
∑wi fi= 1110.
Fw= 1110/20 = 55.5.

7. Conclusion

In our paper we considered the major constraint as breakdown times of the machines. We are dealing with the jobs which are having the distinct job size. The major objective considered here is make span and mean weighted flow time of jobs. From our results it is proved that the mean weighted flow time varies slightly while compared between the processing with breakdown times and without breakdown times. Professor Michael L. Pinedo's Lekin Scheduling system 2.4 contributes more in our paper. All the Gantt charts are made with the help of Lekin scheduling systems. Lekin provides the solution for m machine problems through Local search Heuristics method. Another software tool used in our paper is Lisa (Library of Scheduling Systems) to find the optimality. Hence we complete our objective in our paper successfully.

8. Future Scope

In future the manufacturing trend is mostly flow based advanced production scheme with the use of production algorithms and high tech computers usage in production line apart from in design work. Even though machine break down is minimum it will not be totally unavoidable. Global competition force manufacturers go for advance production shop practice in that context our work is a small plat form to think about it in near and long future

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